

1968

Capacity and trends in use of land resources

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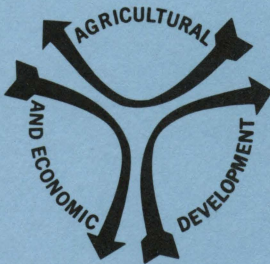
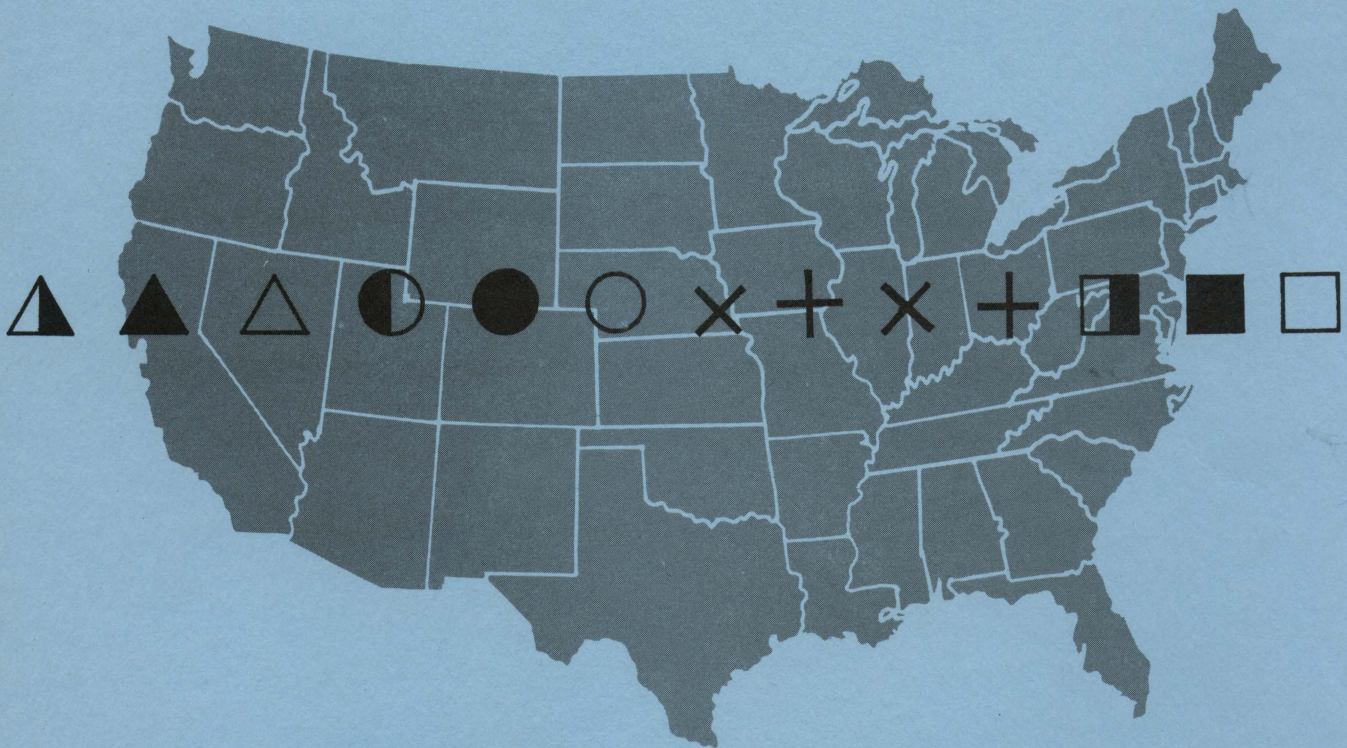
Recommended Citation

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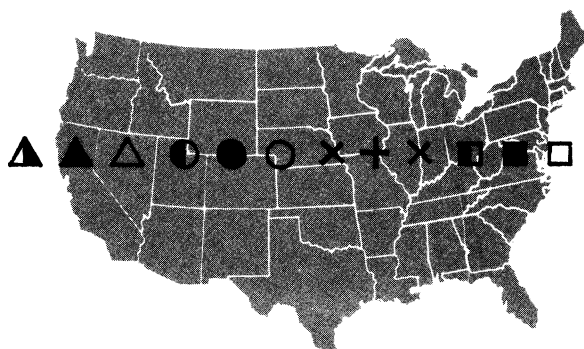
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Capacity and Trends in Use of Land Resources



Center for Agricultural and Economic Development
Iowa State University of Science and Technology
Ames, Iowa, 1968

Capacity and Trends in Use of Land Resources



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**Center for Agricultural and Economic Development
Iowa State University of Science and Technology
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**The Center is supported in part by a grant from
the W. K. Kellogg Foundation**

CAPACITY AND TRENDS

IN USE OF LAND RESOURCES

The nature of consumer demand and its evolution as per capita income grows is one of the forces or variables that alter the use of land and other agricultural resources under economic development. For affluent consumers, such as those of the United States generally, the price elasticity of food demand is extremely low. Reductions in the real price of food cause only slight increases in per person food intake; conversely, rapid increases in per capita output for the domestic market will allow the added output to be absorbed only under a large reduction in farm prices. Hence, with prices considerably stabilized under domestic agricultural policies, the pattern of food consumption is influenced only slightly by its price at the farm.

Population is a second variable affecting demand for food and resource use but, taken alone, it has little effect on the relative use of land or other resources. Its main effect, as a demand variable, would be to alter the intensity of land use, in the absence of advances which substitute new capital technology for land. A more important factor in the relative use of land under national growth is the income elasticity of demand for food, which indicates the percentage increase in food expenditures with each one percent increase in consumer income. For food taken in aggregate and in physical form, the income elasticity of demand for high income consumers is nearly zero, again indicating that, for a highly developed economy, population is still the main variable affecting the overall demand for food. Yet within the food category, there is a considerable difference in income elasticities of demand for individual food items, thus providing a force affecting the relative use of land as national and per capita incomes increase to even higher levels.

The income elasticities are negative for such foods as wheat and other cereals used for human consumption, potatoes, butter, lard, beans and similar products. Hence, per capita consumption of these items declines as family incomes move up. National changes in consumption for these commodities have a negative increment due to economic growth but a positive increment due to population change (See tables 1 and 2). As total consumption still rises, relatively less of the nation's food mix is made up of these commodities and relatively less of its land and other agricultural resources is allocated to them.

Milk products, pork and canned-type vegetables have low positive income elasticities. Hence, while total domestic consumption for these food commodities grows as a result of increases in both population and per capita income, the increase is less than for other foods with higher income elasticities, and relatively less land is devoted to the group. Foods with the highest income elasticities are such commodities as beef and fresh vegetables. Relative allocation of land favors them most under economic growth because their demand increase is weighted most heavily by both population and per capita income growth. Use of land for forest products is even favored rather highly, relative to staple foods, as a result of the changing consumer demand under economic growth. The income elasticity of demand for services which go with food is much higher than the elasticity for food per se. Hence, the premium attached to wrapping, packaging, etc. increases the demand for paper and pulp relatively more than for food.

Table 1. U.S. per capita consumption of selected agricultural products.
(Lbs. per capita unless otherwise noted).

Item	1920	1940	1965	Percent Change 1940-65
Wheat	263	220	160	-27
All Cereals	--	289	235	-19
Potatoes	140	123	89	-28
Cotton	27	30	23	-23
Butter	15	17	7	-62
Dairy Products	736	818	620	-24
Eggs (No.)	299	319	308	- 4
Pork	64	74	59	-20
Beef & Veal	67	62	105	68
Poultry	16	18	41	135
Vegetables	128	180	208	16
Fruit	182	201	179	-11

Table 2. Total U.S. human consumption of selected agricultural products.
(Million)

Item	1920	1940	1965	Percent Change 1940-65
Wheat (bu.)	466	484	512	6
Potatoes (cwt.)	149	162	180	5
Dairy Products (cwt.)	--	1,081	1,190	10
Eggs (10 doz.)	266	351	492	40
Poultry (cwt.)	46	65	137	97
Red Meat (cwt.)	144	188	320	70
Vegetables (cwt.)	127	215	314	46
Fruit (lb.)	179	217	215	-1

The sum effect of these changes in domestic demand forces, as economic growth takes place, is to cause a relative shift of land use away from wheat, field beans, potatoes and dairy products, and toward certain fruits, vegetables and those crops used in beef production. In the framework of demand pattern under economic growth, the total income elasticities for recreation, travel and improved suburban housing are much greater than those for food. Thus, with further national economic growth, we expect relatively more land resources in heavily populated regions to be devoted to airports, roads, suburbs and parks, at the expense of agriculture (See table 3). It is not population growth alone but the differential in income elasticity which causes a migration of land from agriculture to other uses, exceeding the rate suggested by population growth. As is pointed out later, however, this is possible under economic growth which favors the rapid substitution of capital technology.

On the side of domestic demand, substitutes for farm commodities are also important. Demand for man-made fibers has made inroads into domestic cotton consumption because of technological and pricing advantages for the fibers and because of the price disadvantage for cotton as a result of domestic farm programs. Little land will be used for short-staple cotton in the future,

Table 3. Percent change in land devoted to specified uses (harvested acreage for crops), 1940-65 by regions.

Region	Farms	All Crops	Wheat	Soy-beans	Feed Grains	Hay and Pasture Permanent	Cotton	Wood-land
Northeast	-31.1	-27.4	-54.0	+409.0	-23.0	-28.2	0	-19.5
Lake States	-14.2	- 8.5	-32.7	+151.1	-14.9	-26.7	0	+17.5
Corn Belt	- 3.8	+ 3.5	-27.4	+358.8	-11.8	- 3.3	-17.6	+14.0
Appalachian	-25.8	-33.9	-64.2	+726.2	-53.6	+25.7	-43.7	-18.8
Southeast	- 9.3	-45.7	-48.2	+300.3	-65.2	+111.9	-63.5	+ 7.9
Delta	- 5.2	-25.8	+80.3	+381.5	-85.0	-38.3	-44.9	- 3.1
S. Plains	+ 3.1	-29.4	+18.7	+368.0	-45.3	+89.6	-40.5	-14.3
N. Plains	+ 7.8	+ .6	- 1.7	+604.3	- 6.5	+37.7	0	+16.4
Mountain	+39.6	+29.3	+ 8.3	0	+21.1	+53.6	+57.8	+157.5
Pacific	+20.2	+ 7.6	- 9.5	0	+18.8	+40.6	+108.3	+76.0
U.S.	+ 4.6	- 9.0	- 6.5	+620.8	-25.7	+37.2	-42.9	+ 6.7

except as domestic policies allow and encourage it by public purchase and storage of the crop. Under market orientation, even more land used for cotton would shift to other crops in the historic producing areas, while more land would be shifted to long-staple production in the Southwest.

International trade policy and trends also affect the relative demand for domestic farm products and the resulting use of land. Exports of U.S. farm products have been increasing rapidly due to both the commercial and food-aid components. Food aid has been quite largely a result of our own domestic farm policy inadequacies. Commodities included in food aid have been largely a function of our inability or unwillingness to allow intercommodity and inter-regional shifts in the use of our land resources--shifts which are consistent with domestically changing (a) patterns of food demand and (b) technologies affecting the relative quantity supplied and the price of farm products. For example, we produce a greater proportion of wheat, cotton and rice, with the location of production accordingly, than we otherwise would, due to the linkage of our international food aid and domestic farm programs. Some important shifts would have taken place in land use with greater market orientation of our agriculture, or with farm policies which adequately compensated our own producers, but brought the nation's agriculture into better mesh with trends in domestic food consumption patterns and technological possibilities. A large amount of land in the Southern Plains would have been shifted from wheat and cotton to grass and grazing, as would some marginal land areas in the Northern Plains. The concentration of feed grain production in the central Corn Belt, would have been even greater with some further expansion of soybeans in the Southeast to replace cotton. (See tables 3 and 4.) These are the trends expected under a market-oriented agriculture or policies directed to mesh agriculture with changing consumer demand, population location and farm technology. However, the structure of our programs has caused the shift in land use, from crops to nonuse, to be scattered over the entire nation on millions of farms. Acreage quotas thus hold regions toward their historic mold of land use and prevent the extent of intercommodity and interregional shifts that otherwise would have occurred. The rapidity of future land use shifts will largely depend on the framework of farm policies and on the amount and directions of food aid. If we continue food aids as an offspring of our historic regional production patterns, the historic land-use pattern will be prolonged. On the other hand, if we provide more money aid and let the recipient countries buy more corn, grain, sorghum, etc. from us on a least cost basis, shifts would be toward land use patterns of a market-oriented agriculture.

Table 4. Percent of harvested acreage for specified crops grown by regions of the U.S.

Region	Wheat		Corn		Cotton		Soybeans	
	1930	1965	1930	1965	1930	1965	1945	1965
Northeast	3.0	1.6	2.0	3.2	0	0	.9	1.2
Lake States	3.5	3.4	5.1	13.3	0	0	5.7	10.9
Corn Belt	11.2	10.5	35.0	54.9	.8	2.5	83.8	54.7
Appalachian	2.2	1.3	10.5	6.7	6.6	6.5	3.8	6.2
Southeast	.1	.4	9.6	5.5	22.0	13.9	.4	3.8
Delta	0	1.1	5.5	1.4	22.8	23.0	2.8	16.4
S. Plains	11.4	16.6	8.8	1.2	46.4	45.0	.1	.7
N. Plains	49.2	43.7	21.2	13.0	0	0	2.5	6.1
Mountain	13.0	14.5	2.2	.5	.8	3.8	0	0
Pacific	6.4	6.9	.1	.3	.6	5.3	0	0
U.S.	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

To an important extent our barriers to trade in farm products also are a function of our domestic farm policy. Restraints on imports have been in effect to protect the price support levels of our own farm commodity programs. Without these, and with more free trade in agricultural commodities, less of our own land would be devoted to sugar crops, peanuts, feed for dairy products, etc. More would be devoted to the farm products for which we have increasing commercial exports. Favored in the last category would be commodities such as soybeans, feed grains and some livestock products which move to highly developed countries under economic growth. While income elasticities of demand are also low for cereals for human consumption in developed countries, such as Japan or in Europe, the major destinations of our commercial exports, feedstuffs still have high priority as meat consumption increases under economic growth, as point emphasized by figure 1. Hence, commercial export demand especially favors feed grains and oilmeals, as might food aid based on money grants rather than surplus disposal.

Another important set of forces, aside from demand, also attaches to economic development and affects the relative use of land. It affects both the proportion of land used for different food and fiber crops within agriculture and the locations and regions which are devoted to the nation's food production. As with demand, these are forces which change or take shape with further economic growth and hence cause shifts in land use to be a "natural" consequence of that growth. They relate to the supply quantities and prices of resources, particularly capital. One characteristic of economic growth is the increase in supply of capital and the reduction in its price or cost relative to that of other resources such as labor and, to an extent, land. As the price of capital declines, more of it is used as a substitute for other resources. Consequently, over the last 25 years, American farmers have substituted about \$50 billion for 4 million workers and 60 million acres of land (the land both held out of production by government programs and transferred to nonfarm uses. Actually the substitution is even greater, since output also increased by 70 percent over the period). The real price of capital continues to decline and this substitution will progress even further. Compared with the cost of labor, the decline in real price over the last 25 years has been 70 percent for fertilizer, 50 percent for farm machinery, and 40 percent for all capital items. Compared with crop prices, the real price of fertilizer has declined by 40 percent in this period. Hence, the encouragement to use more capital causes a direct substitution of this resource for labor in the case of mechanization, and also an indirect substitution, as

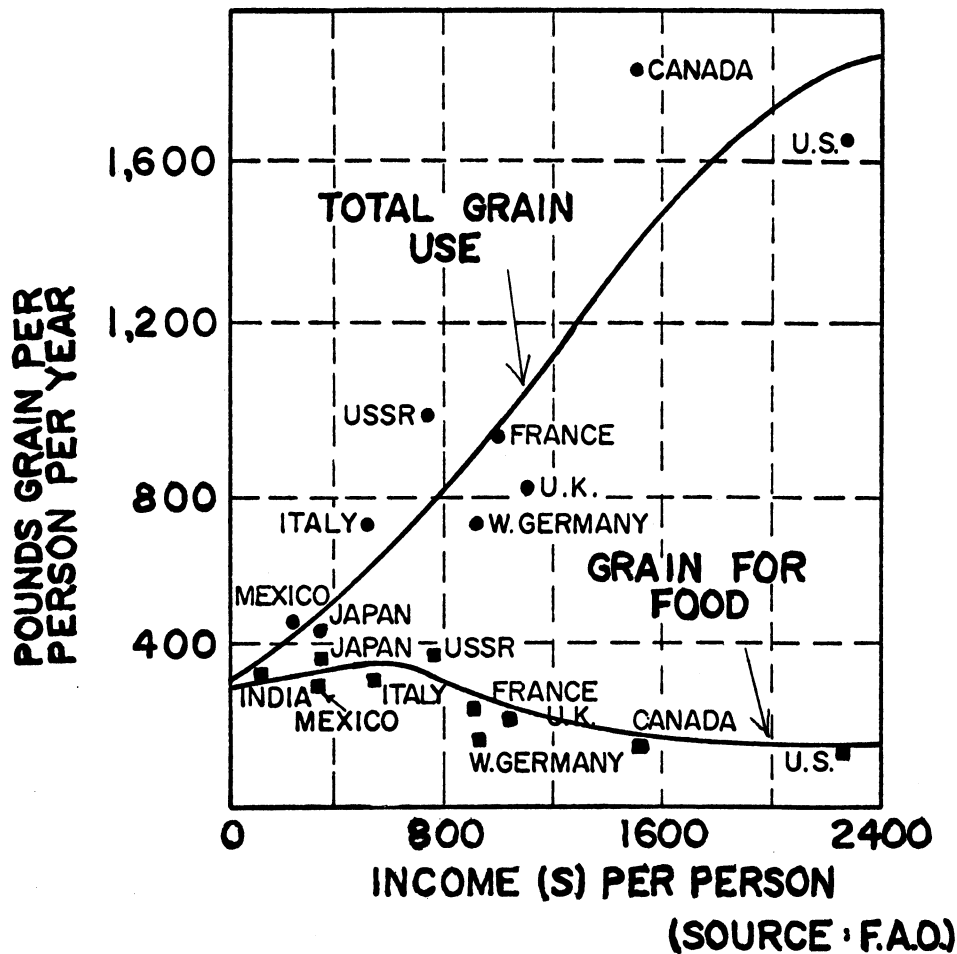


FIGURE 1. RELATION OF PER CAPITA ANNUAL INCOME TO GRAIN CONSUMPTION PER PERSON FOR FOOD AND TOTAL USES.

higher crop yields from biological forms of capital allow fewer acres and laborers to produce the nation's food needs. The capital also substitutes directly for land, since fewer higher-yielding acres are needed to meet demand for crops, and indirectly because the substitution of capital for labor causes farms to become more specialized and to alter their land use patterns.

Capital supplies and prices which cause more capital to be used have these effects on land use: Greater capital employment raises the fixed costs of farming due to the need for specialized equipment. When reliance is mainly on labor, this resource can be transferred rather flexibly from one enterprise or crop to another. But when reliance is mostly on large investments in specialized machines, fixed costs can be spread over sufficient volume for lower unit costs, and a positive profit margin, only if there are fewer but larger enterprises on the farm. Individual farms specialize more in use of land and other

resources and the specialization tends to concentrate in regions. Thus, the more productive soils of the Corn Belt are tending to specialize more in grain crops (See table 4) and single livestock enterprises. There are many fewer farms which produce pork, dairy products, beef and poultry but they are much larger than 25 years ago. As an example of this momentum in the U.S., changes respectively in the number of farms producing the item and national production were as follows in even the 5-year period, 1959-64: eggs, 47 percent fewer producers but 29 percent greater output; dairy cows, 37 percent fewer farms but 10 percent greater milk output; hogs, 42 percent fewer producers but 3 percent more hogs; cattle and calves, 15 percent fewer farms but over 20 percent more animals. In the same period, there were these declines (much greater than the decline in the total number of farms) in the percentage of farms producing particular crops: corn, 28 percent decline; peanuts, 34 percent decline; potatoes, 55 percent decline; cotton, 36 percent decline; and tree fruits, 30 percent decline. The changes implied in specialization mean a much greater change in land use for the individual farm than for the nation, or even for the region. At the same time, more farms are specializing in cash grain sales. Consequently over the major soil areas of the Lake States and Corn Belt, the amount of land devoted to hay and pasture is decreasing. While this shift in land use results indirectly from the substitution of capital for labor and the encouragement of larger and more specialized farms accordingly, it results also from the substitution of capital inputs from industrial sources for natural sources or inputs. Examples are chemical fertilizers, pesticides and insecticides. These industrial inputs now supply the fertility and the weed and insect control that formerly came from legumes and hay grown in the rotation.

Together, this set of substitution forces is having an important impact on land use in major field grain areas and the trend will continue over the future. Of course, through this process, feed grain production tends to become centered more, to the extent allowed by current farm programs, and (as emphasized in Table 4) in the soil and climatic regions most suited for grain production. Consequently, as an indirect and chain effect, certain other regions less adapted to these crops by natural forces and location have a declining comparative advantage and the tendency, as allowed or encouraged by government programs, to concentrate on other uses of land.

Economic development and the substitution process have even broader impacts on the use of land among crops and regions. Most modern farm capital inputs supplied from industrial sources, particularly those of biological forms, are direct substitutes for land. As an example, if an acre of land produces 50 bushels of grain without fertilizer and 80 bushels with 40 pounds of nutrients, we have this arithmetic result: 4,000 bushels can be produced with 80 acres and no fertilizer or with 50 acres and 2,000 pounds of fertilizer. Computing some fertilizer-land substitution functions, we have found that--for the several sets of data available -- a ton of nutrients substitutes for 23.6 acres at conventional levels of fertilizer use in corn production.^{1/} (The rate of substitution will

^{1/} See Earl O. Heady and Luther W. Tweeten, Resource Demand and Structure of the Agricultural Industry. Iowa State University Press. Ames, 1963. pp. 106-117.

The estimates are made through the following procedure: If the per acre fertilizer response function is where Y is yield and F is the amount of nutrients

vary, of course, by crop, location and rate of use.)

This "average rate" is for substitution of fertilizer on the land where it is used. Naturally, as capital is used on land, the land at the location does not move out of production but has even more advantage in production if it is particularly adapted to the crop in question. The advantage of this land is raised relative to land at another location which does not respond similarly to fertilizer, improved varieties, herbicides, insecticides, etc. Hence, as production increases relative to demand, the shift out of the crop in question tends to take place at locations other than the point of application of capital technology and, in acreage measurement, the substitution is even greater. In the example of the 23.6 acres substitution rate mentioned for corn, the amount of land substituted for or released from production of the particular crop at another location with half the yield will be 47.2 acres of land--as a result of the ton of nutrients. Hence, as a result of these effects, the region using the capital innovation at high intensity becomes more specialized in the crop to which it is applied while another region with similar advantage but without the capital innovation will tend to shift land to other uses. An example again is the greater concentration of corn in the Lake States and Corn Belt and their contraction in the Plains regions, and a shift of cotton to the Southwest. While our conventional farm programs, with acreage quotas and direct payments for compliance, have tended to check this interregional and intercommodity shift in land use, the trends are still apparent as farms specialize more in grains.

Economic development and the lowering of capital prices relative to other resources also tends to lessen the relative importance of land in food and fiber production. If we could measure the physical services of land along with those of capital and labor, we would find that each unit of food product now embodies a much smaller proportion of both land and labor services and a larger proportion of capital services than in decades of the past. This point is rather obvious since we now produce twice as much as in 1925 with 56 million fewer acres devoted to crops and 60 percent fewer workers. On a value basis,

$$V = a + bF - F^2$$

in the customary ratio, the actual (per acre) function is as follows where

$$(Y/A) = a + b(F/A) - c(F/A)^2$$

A is acres. (The usual fertilizer response trait is adjusted so that A=1.) This per acre function, if multiplied by the number of acres to which fertilizer is to be applied, thus is as follows where both land and fertilizer are incorporated into the function as variables:

$$Y = aA + bF - F^2A^{-1}$$

From this equation, the isoquant of yields is:

$$A = (2a)^{-1} [Y - bF + \sqrt{4acF^2 + (Y - bF)^2}]$$

And the marginal rate of substitution of fertilizer for land is:

$$\frac{\partial A}{\partial F} = \frac{2cF - b}{a + cF^2}$$

land services now make up only about 15 percent of total input services used by American agriculture. (But part of this value of land services results from the increment due to support prices. Land and its services otherwise would have a considerably smaller value and represent an even smaller proportion of total input services on a value basis.) This decline in the relative contribution of land in the production process also changes the relative contribution of land in different locations. With current capital technology represented by chemicals, insecticides, pesticides and herbicides, some of the lower yielding soils of the southern and other parts of the Corn Belt with favorable moisture are gaining in relative advantage with soils formerly considered to be much better because of topography, organic matter, profile, etc. Yield gaps are beginning to narrow and, in many cases, soil type is much less important than it was at a previous time.

The sum effect of these substitutions, technological changes and shifts in specialization is to provide a strong impetus to a complex realignment in regional specialization in land use. If crop production were purely market oriented, marketing quotas did not serve as a restraint and the full producing capacity of American agriculture were unleashed in the market, we would have wide expanses of less productive Plains regions and parts of the Southeast shifting out of field crops and into grass and less intensive farming. (See trends in tables 3 and 4.) On the other hand, grain producing areas of the Corn Belt, the central wheat areas and other regions of favorable climate and soils would specialize much more, or almost entirely, in grain production.

These would be mammoth shifts in land use by regions and commodities. These shifts in land use would, of course, be accompanied by what might be considered to be inequitable distribution of the gains and sacrifices or costs of structural adjustments in land use and agriculture. The trend is already present, but at a slower pace than would prevail in a purely open market. The spatial redistribution of land use among grains and forages brings more intensive farming to some regions, and thus does not cause labor to leave so rapidly. Hence, business is retained for local merchants, teachers, government officers, etc., in these regions. But in regions shifting to less intensive land use, as from row crops to forages and grazing, farms become larger and fewer and a smaller farm labor force is required. Consequently, there also is a reduced volume of business for local merchants and less tax base and patronage for schools and other rural institutions. Income declines for much of the rural business and service sector as the cost of spatial redistribution falls particularly on it. Many rural communities are now in this process of depopulation and relative or absolute income depression. It is on them that the major cost of farm technological advance and spatial redistribution of land use falls. While these sectors of the rural community are bearing the costs or sacrifice, the nation and its consumers are realizing a gain as the real price of food declines, as labor is released from farming for production of other goods and services, and as some land is shifted to those nonfarm uses attached to high income elasticities. Farm programs which tend to preserve the present interregional pattern of land use will be favored or forced through the political mechanism as long as the distribution of the gains and costs of agricultural advance follows its current pattern. We are not likely to have programs which aid or allow a full spatial redistribution of crop production, consistent with modern food demand structure and farm technological opportunities, until we fashion programs which provide adequate compensation or economic opportunities to those sectors of the rural community which otherwise bear the brunt and social costs of these changes.

The spatial redistribution of land use, with the reflection in the type and extent of crop specialization, is more extreme than changes in the relative national distribution of land among crops. As table 5 indicates, changes in the percentage of U.S. harvested acreage devoted to such crops as wheat, corn and feed grains totally have been rather modest, as compared to the regional changes indicated in table 4. Or, in other words, the changes occurring in land use are much greater than those reflected in national aggregates.

Table 5. Percentage of U.S. harvested acreage devoted to specified crops by time periods.

Crop	1920	1940	1965
Wheat	17.7	15.3	16.0
Corn	25.3	22.3	18.6
Feed Grains	40.7	38.1	32.2
Cotton	9.8	6.9	4.4
Soybeans	--	1.4	11.2
Vegetables	.4	.9	.8
Fruit and Nuts	1.3	1.2	1.0

FUTURE PATTERNS

Trends in land use over the future will reflect the tendencies and variables already discussed. To measure the shifts in land use which are posed, I have applied large-scale linear programming models to the nation's agriculture, projecting the changes which are prospective under different assumptions of the market and farm policies. These models consider the interdependence of the many producing areas in respect to their comparative advantage as reflected in soils, climate, technology used, location of consumer markets, etc. Since current farm programs tend to hold land use to its historic mold, or restrain the rate at which interregional shifts can take place, some of these projections are made to indicate the spatial pattern agriculture might follow if these restraints were removed, or if farm programs were designed to bring them about while adequately compensating those rural community sectors which would otherwise suffer losses as a result of them.

For this analysis, the United States has been divided into 144 producing areas and 31 consuming regions. The 144 producing areas are those indicated in figure 2 by number. Regions without numbers were not included in the analysis because they have few of the crops analyzed and will probably continue reducing them in the future. The models are designed to show (a) the most efficient pattern of land use in terms of the costs of producing, transporting and processing farm products as these elements relate to the different producing areas and consuming regions, and (b) the amount and location of land which could be shifted from crops to grass and trees, if the nation's agricultural pattern were most efficient. Restraints observed include the maximum amount of land in each producing area, the upper limit on land which can be used for any one crop, the demand for livestock feeds and human foods in each producing area and consuming region, etc. Some of our current models involve around 4,000 equations and 37,000 variables. Results are reported here for a somewhat smaller model (850 equations) which gives essentially the same spatial results in land use.

In the main analysis, technological trends were projected for each of the 144 producing areas based on 1950-65 data. Hence, the projections are probably conservative and we would expect changes of somewhat greater magnitude under expected upcoming technologies and in the absence of restraining farm programs. The analysis includes wheat, corn, oats, barley, sorghums, cotton and soybeans. It relates to three time periods and different assumptions of export demand: (1) 1965, to determine what the optimal interregional pattern of land use would have been in the absence of restraining farm programs. (2) 1975, to examine the balance between growth in domestic demand due to population and income increases to that time when (a) all regions retain technological trends equal to those of the 1950-65 period and (b) areas of the Southeast step up the rate of technology to levels approaching other producing areas of the United States and (3) 1980, to examine the effects of alternative levels of exports on land use in the 144 producing regions. All of these applications suppose that crops are allocated most efficiently among the 144 producing regions in meeting domestic and export demands.

1965 patterns

Figure 3 indicates the regional distribution of crop acreages for the 1965 model. As compared to the actual 1965 production pattern, in the absence of restraining farm programs, and an optimal spatial distribution of land use, feed

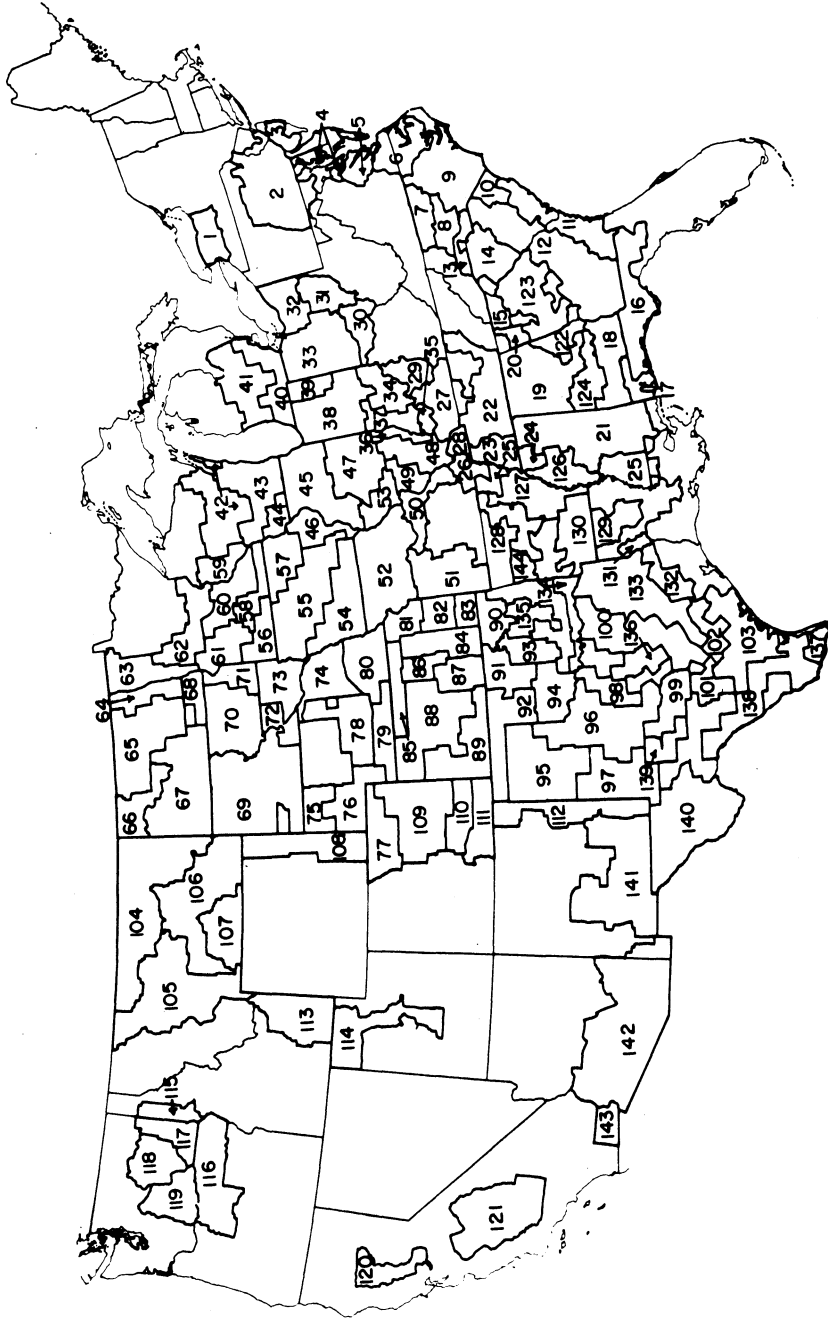


FIGURE 2. LOCATION OF THE 144 PRODUCING REGIONS USED IN THE STUDY.

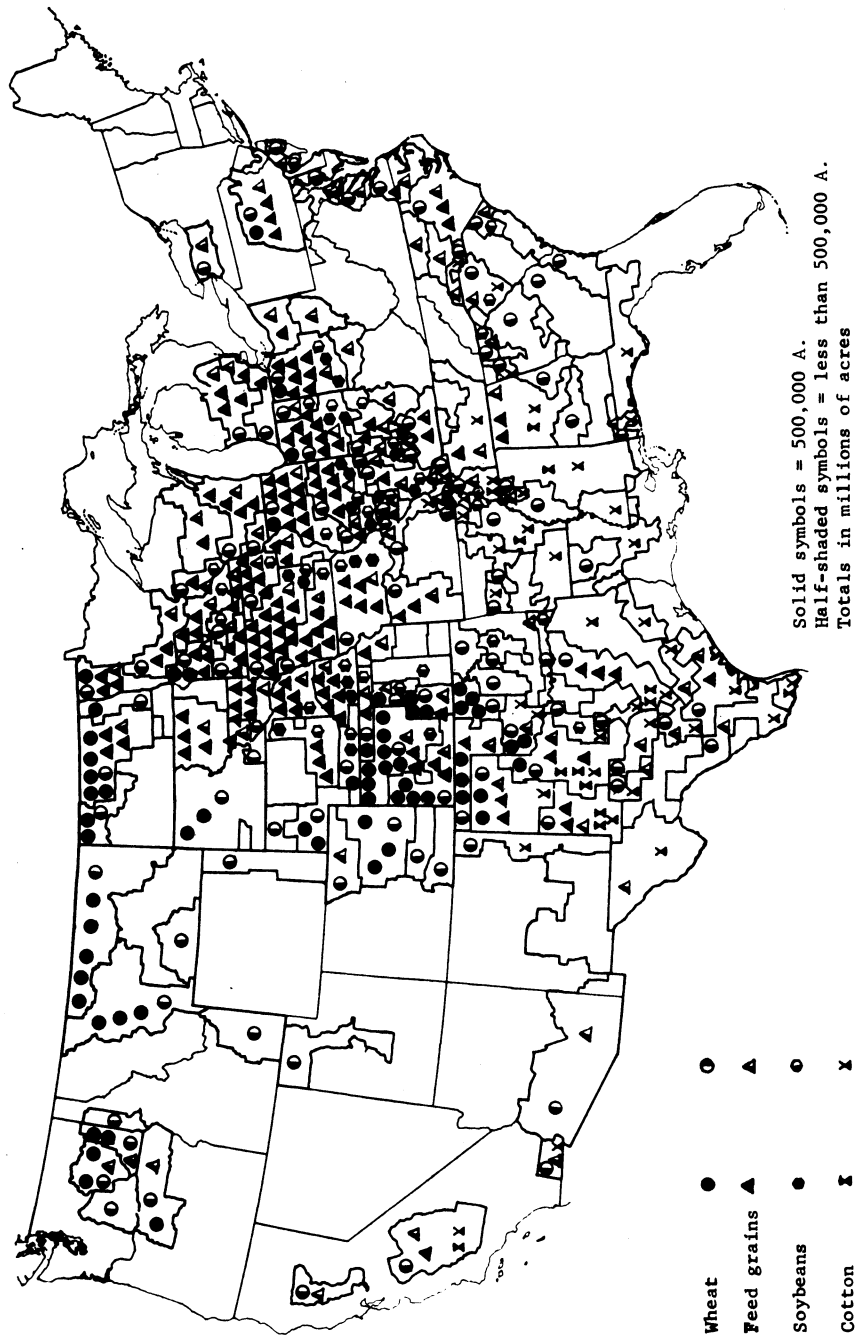


FIGURE 3. REGIONAL LOCATION OF PRODUCTION UNDER OPTIMAL LAND USE FOR 1965.

grain acreage would shift more to the Corn Belt proper, with smaller acreages elsewhere -- especially in the Northern Great Plains. Wheat acreage would be smaller in the Corn Belt and the South and larger in the major producing areas of the Great Plains and the West. (Under this solution, with price differentials removed for wheat used as feed and food, an additional 310 million bushels would be used for livestock feed.) Cotton production would shift somewhat from the Southeast to the Southwest. (Distinction was not made between short-staple and long-staple cotton in this analysis. If a price and demand penalty is attached to short-staple cotton, the shift is more dramatic.)

Figure 4 indicates the amount of land which could be considered "surplus" under this model, in terms of national and export demand and the comparative advantage of the different regions. This is land which could be shifted to less intensive uses such as grass and trees, if the nation's production pattern has been optimal in terms of given domestic and export demand and the technology or relative advantage estimated for the 144 producing regions. This land is highly concentrated in the Southeast and the Great Plains, the northern part of the Lake States and the Atlantic Seaboard.

1975 patterns

Figure 5 includes the projected results for 1975 under the assumption of (a) projected growth rates in U. S. population and per capita incomes, with food demand adjusted accordingly, (b) exports for grains doubled over the 1956-61 level (about current trend rates), and (c) technological trends for each of the 144 producing regions equal to those realized over the 1950-65 period. Also, it is assumed that most of the increased exports of feed grains and soybeans move to Europe while the increase in wheat exports moves to the Far East and the Middle East. In this model also, the major areas of land which could be shifted to grass and trees and other non-crop or less intensive uses are in the Great Plains and Southeast.

Figure 6 includes the projected results for 1975 under the same demand conditions as for figure 5. However, for figure 6 we use projected technology based on 1950-65 trends for all producing regions including those of the Southeast. For producing areas in the Southeast (Virginia to Kentucky through Louisiana and all states to the South and East) we now assume (1) the same degree of mechanization as for other producing regions in the nation, and (2) that fertilizer application is stepped up to levels already known to be economically feasible by operating farmers with sufficient capital. In other words the technological lag of the Southeast is partially removed in this solution.

Under these conditions, and supposing an optimal inter-regional allocation of crop production, a large change would occur in land use and in the spatial distribution of crop production. A large acreage of feed grains and soybeans would move into producing areas of the Southeast. More of the land to be shifted to less intensive uses, such as grass, would now fall in the Great Plains and Corn Belt fringe areas.

These comparisons suggest that with a step-up in technology, a restructuring of farms to allow larger units and mechanization and the availability of capital, producing areas of the Southeast could compete strongly with the rest of the country in intensifying land use and in producing major crop needs.

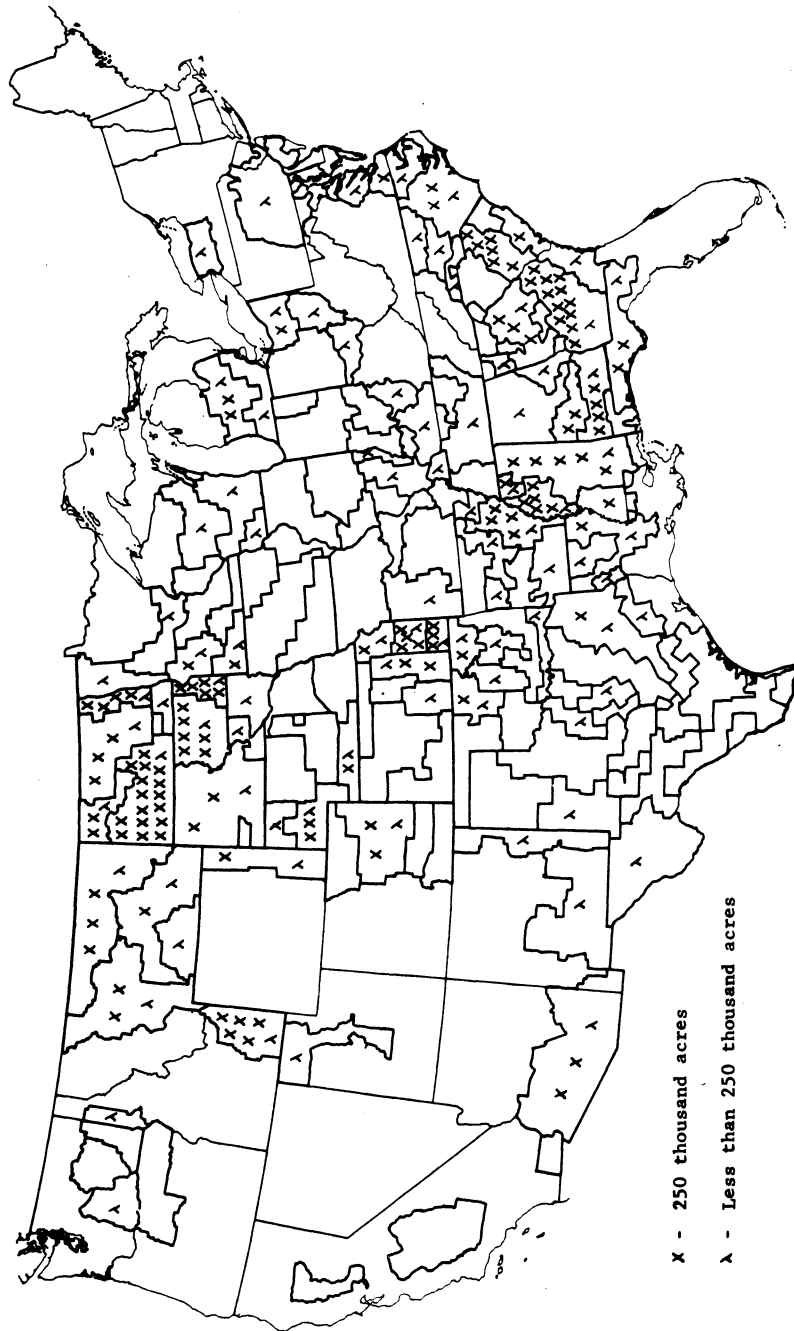


FIGURE 4. LOCATION OF LAND WHICH COULD BE SHIFTED TO GRASS AND TREES UNDER AN OPTIMAL DISTRIBUTION FOR 1965.

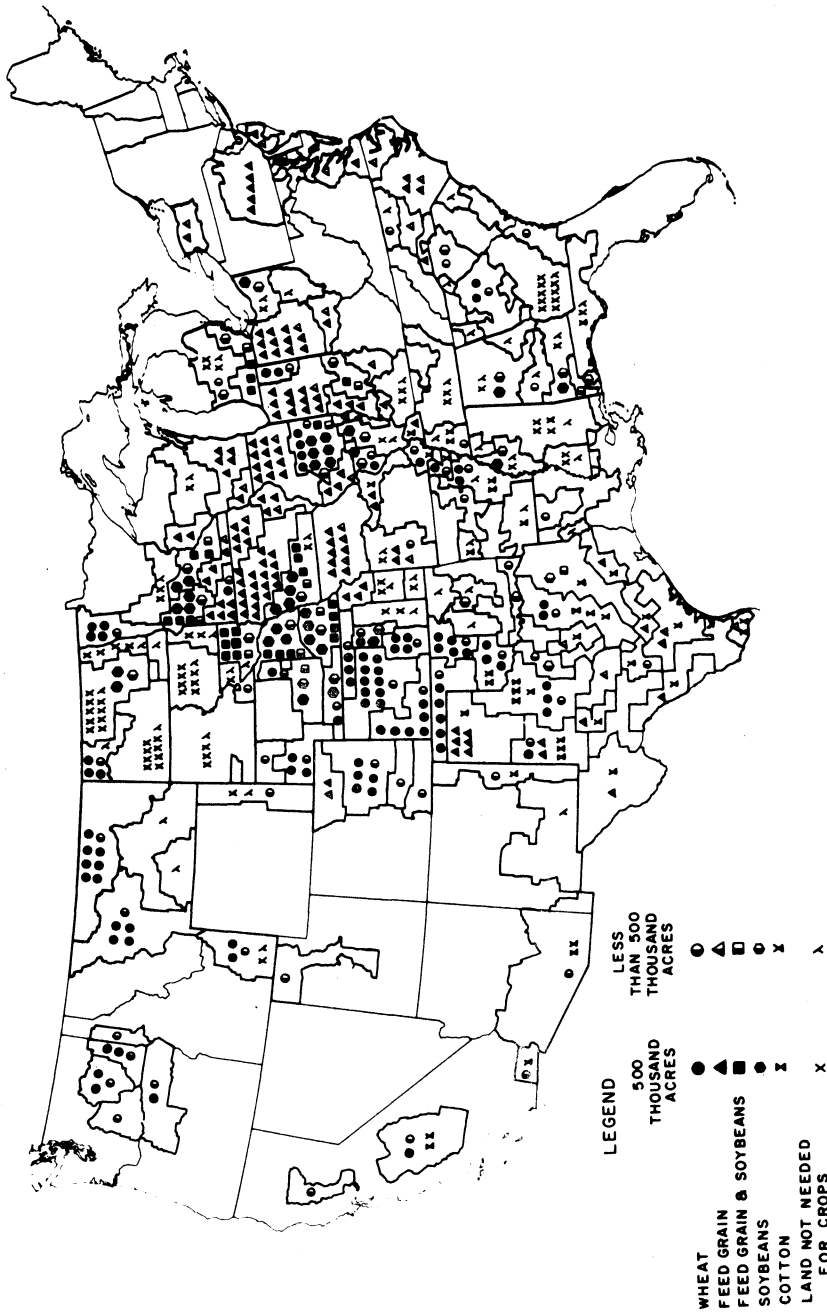


FIGURE 5. LAND USE PATTERN INDICATING OPTIMAL DISTRIBUTION OF CROP ACREAGE FOR 1975 UNDER PROJECTION OF 1950-65 TRENDS IN TECHNOLOGY FOR ALL 144 PRODUCING AREAS.

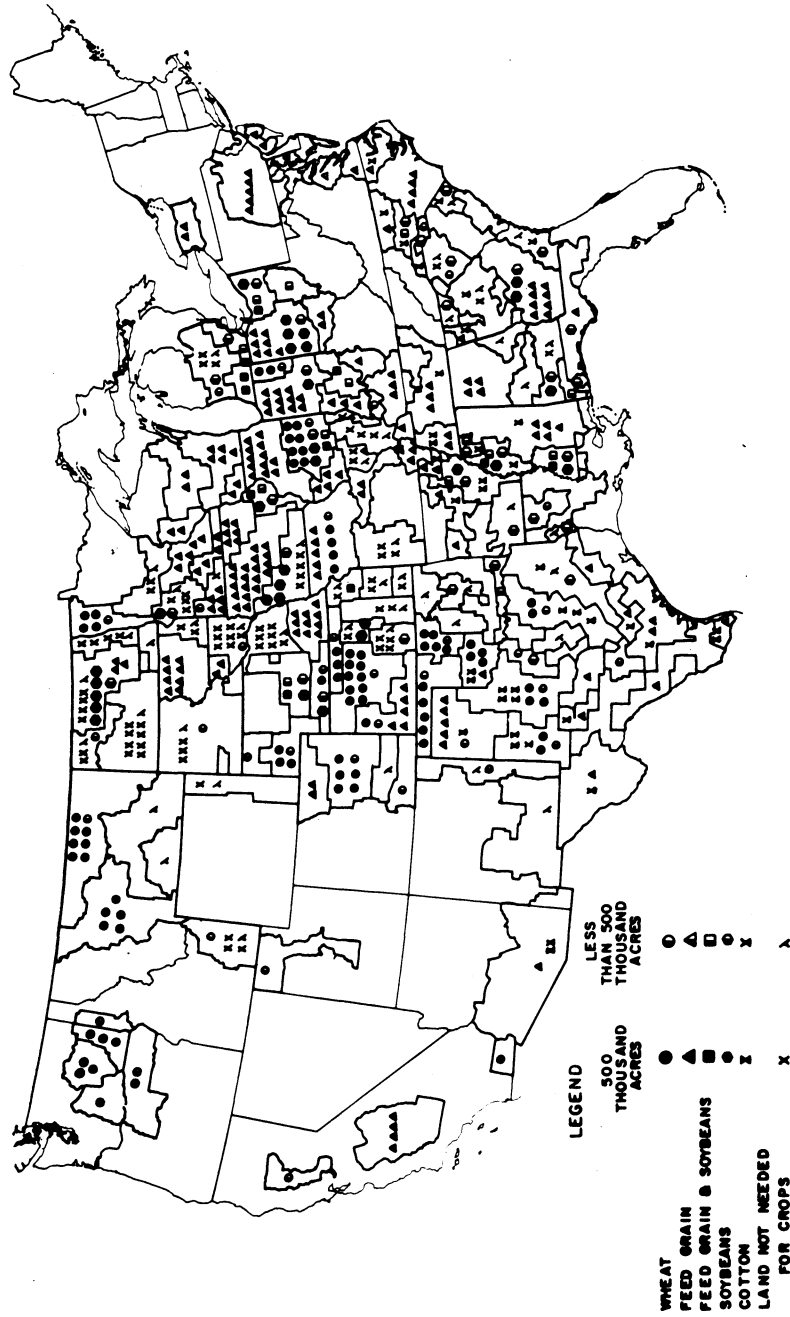


FIGURE 6. LAND USE PATTERN INDICATING OPTIMAL DISTRIBUTION OF CROP ACREAGES FOR 1975 WITH RELATIVE IMPROVEMENT IN TECHNOLOGY FOR THE SOUTHEAST.

1980 patterns

Estimates for 1980 were made without the special technological advantage for the Southeast (i.e., the technological trends over the 1950-65 period were projected to 1980). Domestic demand was projected in the manner explained above. However, two levels of export demand were used: (a) total commercial exports and international food aid at the 1965 level and (b) total exports at the trend level, or approximately three times the 1965 level. The results for these computations and projections provide a pattern paralleling figure 5 in the distribution of crops and land which could be shifted to less intensive use.^{2/}

Using these demand and technology conditions for 1980, the projected cropland acreage which could be shifted to grass and trees or other extensive uses is 78.5 million acres at 1965 export levels. As is indicated in figure 7, these shifts in land use would be heavily concentrated in the Southeast and Northern Plains and somewhat in the Southern Plains. With exports at trend levels, or three times 1965 exports, 47.0 million acres would be "surplus" for crop production (in the sense of "just" meeting the demands outlined above and without accounting for larger disappearance if prices were turned loose in the market at levels lower than current real prices). The distribution under the potential land use shifts posed for the larger export demand and, as illustrated in figure 8, withdrawal of land from field crops would still be concentrated in the Southeast and the Great Plains. The greater employment of land for crop production would lessen the land potentially to be shifted from crop production in the Corn Belt.

The 1980 estimates, as mentioned previously, suppose that the trends in technology and yields of all 144 regions will follow the rates experienced over the period 1950-67. However, as illustrated for figures 5 and 6, if the structural adjustments of agriculture in the Southeast could be hurried and this broad region were to step up the level of technology to that already economically feasible, the national results for figures 7 and 8 would be greatly modified. Not only would much less of the land to be shifted concentrate in the Southeast, but also a greater amount of land could be shifted from crops at the two export levels indicated.

^{2/} When we refer to land which could be shifted, we include land already included in conservation reserve, cropland adjustment, feed grain, cotton and other acreage diversion programs. The acreage against which these potential shifts are compared is the total base acreage for crops, with the base representing the maximum acreage of individual crops grown in the area up to 1955. However, for 1980, the base acreage has been adjusted to recognize the shift in land out of forages to grains in the Corn Belt and similar regions. For other explanations of these base acreages, see: Earl O. Heady and Melvin Skold. Projections of U. S. Agricultural Capacity and Interregional Adjustments in Production and Land Use with Spatial Programming Models. Iowa Agr. Exp. Sta. Bul. 539; and Earl O. Heady and Leo V. Mayer, Projected Structure and Capacity of American Agriculture. Mimeographed Report. Iowa State University. January, 1967.

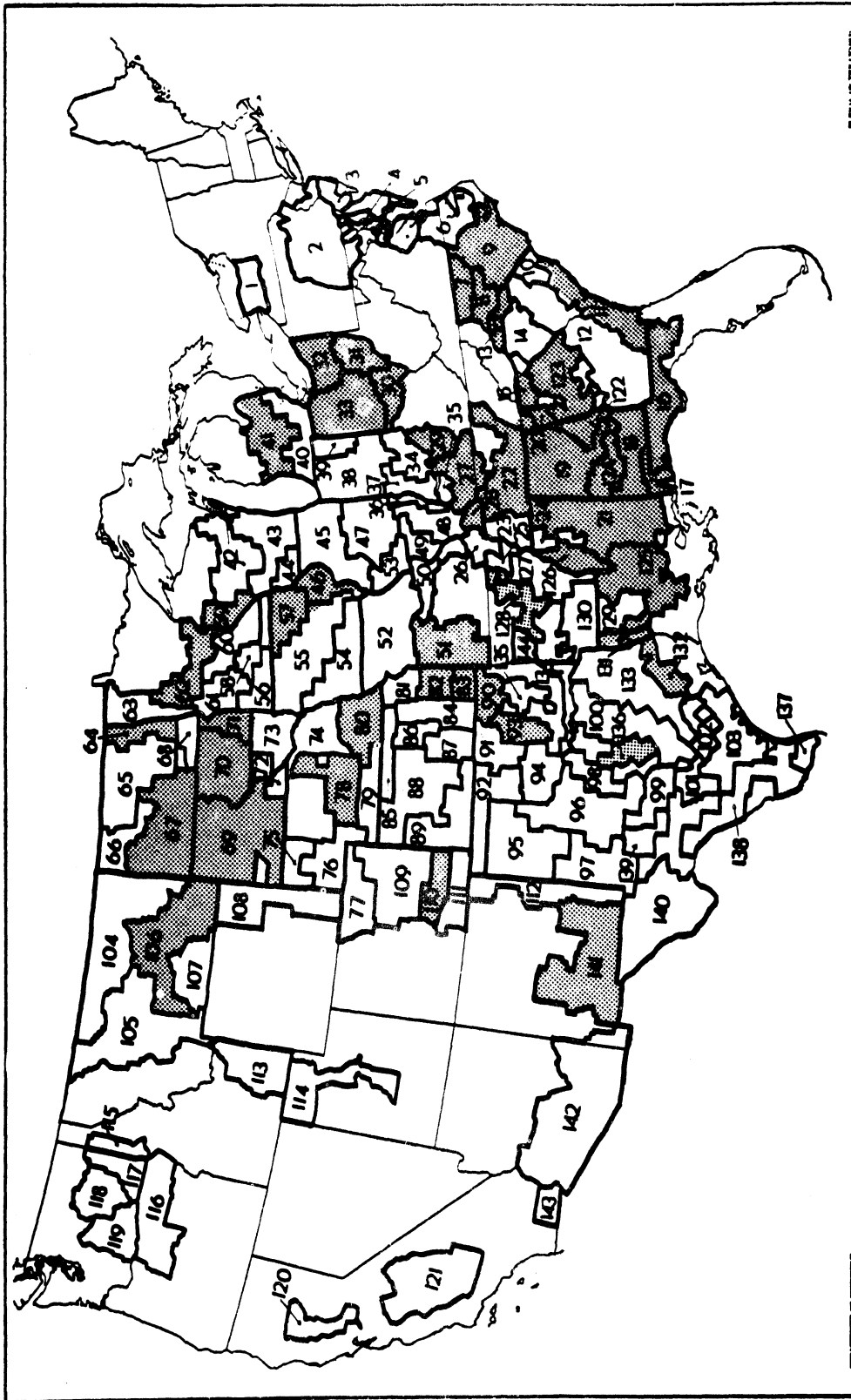


FIGURE 7. 1980 PATTERN OF LAND USE SHIFTS FROM CROPS TO GRASS AND TREES. 1950-65 YIELD TRENDS PROJECTED TO 1980 AND EXPORTS AT 1965 LEVELS. DARKENED AREAS ARE THOSE WITH MAJORITY OF CROPLAND AVAILABLE TO SHIFT FROM CROPS TO OTHER USES.

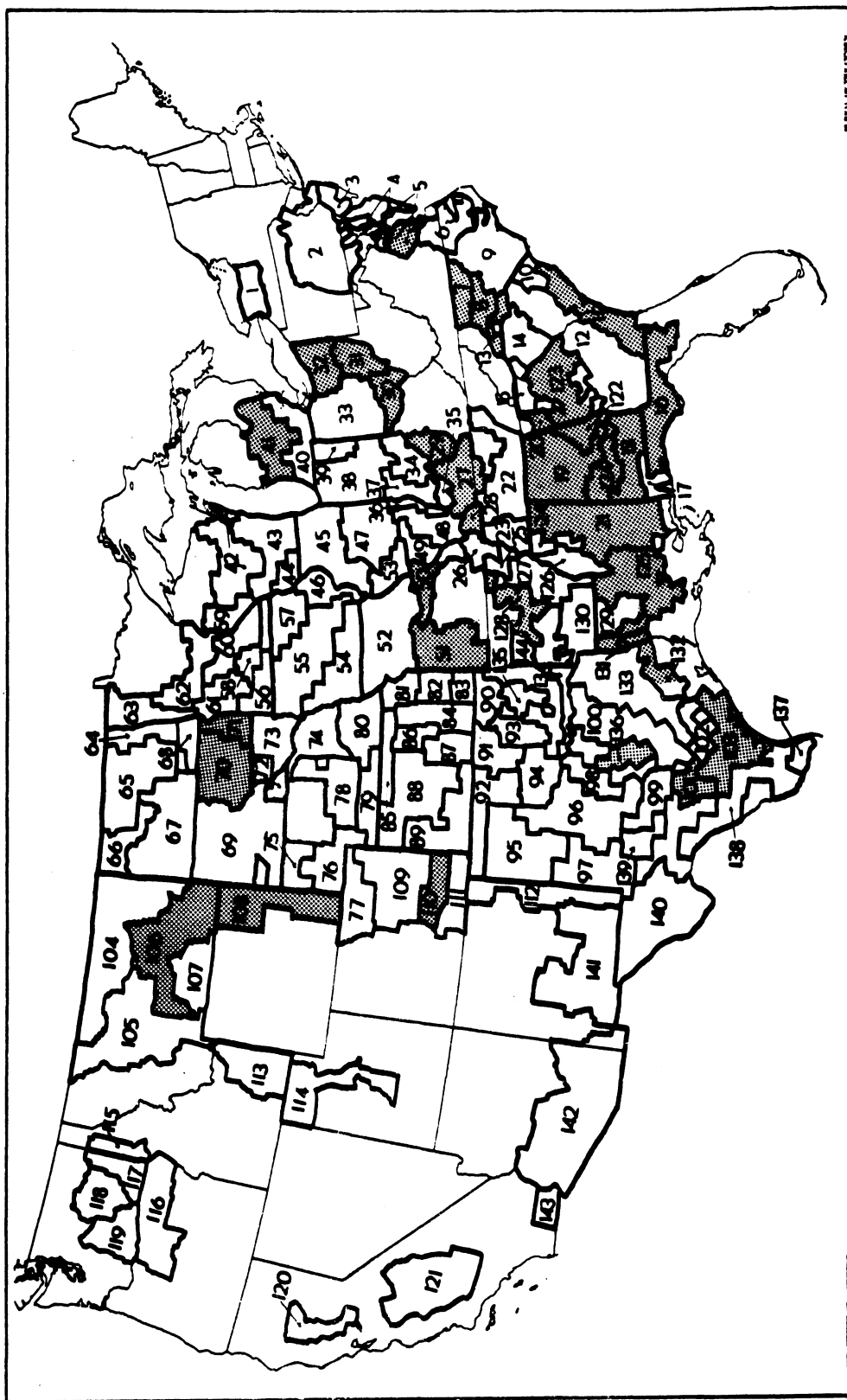


FIGURE 8. 1980 PATTERNS OF LAND USE SHIFTS FROM CROPS TO GRASS AND TREES. 1950-65 YIELD TRENDS PROJECTED TO 1980 AND EXPORTS AT THREE TIMES 1965 LEVELS. DARKENED AREAS ARE THOSE WITH MAJORITY OF CROPLAND AVAILABLE TO SHIFT FROM CROPS TO OTHER USES.

Land Use Shifts and Adjustments of the Rural Community

The above analysis indicates that the nation's producing capacity will continue to be large relative to domestic demand as improved capital technology is further substituted for land used in crop production. Even with a threefold increase in exports, nearly 50 million acres would be rather permanently shifted out of the nation's cropland base. The figure might prove to be even more, since 1950-65 trends in technological improvement may prove to be conservative for the future.

A threefold increase in exports is rather large for a 15-year period, starting from a base which is already sizeable with its food aid component. It is, of course, possible that the U. S. may be called upon to furnish more food aid in the stormy world political period ahead, and in this intermediate period when less developed countries are gearing up both their own production potential and population control programs. This slack capacity summarized above could help greatly in meeting any increments in demand so arising. In addition, it is estimated that at a 50-billion-dollar investment, the nation could draw another 150 million acres into crop production.^{3/} It could be rather foolish for us to strike out now, in the expectation that we will be called upon to make food contributions of this magnitude, and begin investing in this land reclamation and conversion. Before we take these steps, we need to bring land use into reasonable interregional and intercommodity balance with current demand and technology. Our farm programs of the last five decades have prevented us from doing so, as acreage quotas and restraints have been distributed over all producing regions under the assumption that our commercial farm problem is a temporary one -- that given a few years to live out the "rough spots" in supply and demand, it will evaporate. However, in this continuous extension of short-run emergency programs, we have invested over \$60 billion and the problem has prospects of being with us for some time into the future. Under the existing pattern of land use shifts, a few acres on each farm to control supply, permanent reallocations are not made in the use of our land resources. The long-run shifts needed in light of demand and technology trends can be attained only if we make intercommodity and interregional shifts in the general manner outlined in this study.

Obviously, however, we are not likely to make them until we devise efficient means for compensating the rural community in the broad sense. To concentrate the adjustment by regions according to present technology, interregional comparative advantage and current location of population and demand, we could pay farms to make them as well or better off in doing so. But it would mean rapid shifts in the intensity and sizes of farms. With a smaller farm population accordingly, the volume of business and the supply of services decline for others in country towns of the rural community. Thus, while we may solve the capacity problem and the income of farm families in the intensely adjusting regions, we transfer an income problem to others of the rural community. Undoubtedly, this threat or possibility helps to explain our format of 'land withdrawal over the entire country,' and the political resistance to programs of the Soil Bank or Conservation Reserve type tried in the past.

^{3/} M. L. Upchurch. The Capacity of the U. S. to Supply Food Proceedings: Alternatives for Balancing World Food Production and Needs. Center for Agricultural and Economic Development. Iowa State University Press. Ames, 1967. p. 219.

Hence, optimal spatial redistribution of land use in the nation is complexly interlaced with the problems of the rural community in general. We are unlikely to solve the problems of land use and capacity until we develop appropriate and politically and economically acceptable programs for rural communities faced with declines in capital values and business volume. Many rural towns are faced with this prospect, just from the substitution of modern technological capital for labor and a consequent increase in size and reduction in numbers of farms, without occurrence of the basic land use shift. Some programs useful to the rural community would include: (1) larger investment and greater state and federal aid to education and vocational training to improve economic opportunities in the "outside economy," (2) a more effectively 'nationalized' employment service to better connect people with job opportunities, (3) retraining facilities in the rural community, even with some unemployment compensation to underemployed persons, encouraging them to participate in these services, (4) earlier eligibility for old age or social security payments and minimum income levels for all older persons in rural areas, (5) greater planning aids and facilities for the rural community, and (6) mechanisms where several rural communities can act jointly in providing services and financing improved institutions at a lower cost. This and other policy means are necessary before we can have an equitable distribution of the costs and benefits of interregional land use shifts.

Appendix

The structure of the linear programming model underlying the results in figure 3 through figure 8 is as follows:

We use a cost minimization model in all cases which is stated as (with the term activity referring to each crop produced)

$$\begin{aligned} \text{Minimize } f(c) = & \sum_{i=1}^{144} \sum_{k=1}^5 c_{ki} x'_{ki} + \sum_{m=1}^{31} d_m Y_m \\ & + \sum_{g=1}^3 \sum_{m=1}^{31} b_{gmm'} z_{gmm'} \end{aligned} \quad (1)$$

in which

c_{ki} = cost per acre of producing the kth activity in the ith programming region,

x'_{ki} = level of production of the kth activity in the ith programming region,

d_m = cost per unit of transferring wheat into feed grains in the mth consuming region,

Y_m = quantity of wheat transferred into feed grains in the mth consuming region,

b_{gm} = cost of transporting a unit of the gth product from (to) the mth consuming region to (from) the m'th consuming region,

z_{gm} = quantity of the gth product transported from (to) the mth consuming region to (from) the mth consuming region.

Equation 1 is maximized subject to the linear restraints:

$$D_{1m} = \sum_{i=1}^r a_{1i} x'_{1i} - h_m Y_m \pm \sum_{m'=1}^{31} t_{1mm'} z_{1mm'} \quad (2)$$

$$\begin{aligned} D_{2m} = & \sum_{i=1}^r a_{2i} x'_{2i} + \sum_{i=1}^r a_{3i} x'_{3i} + h_m Y_m \\ & \pm \sum_{m'=1}^{31} t_{2mm'} z_{2mm'} \end{aligned} \quad (3)$$

$$\begin{aligned} D_{3m} = & \sum_{i=1}^r a_{3i} x'_{3i} + \sum_{i=1}^r a_{4i} x'_{4i} + \sum_{i=1}^r a_{5i} x'_{5i} \\ & \pm \sum_{m'=1}^{31} t_{3mm'} z_{3mm'} \quad \text{and} \end{aligned} \quad (4)$$

$$D_c = \sum_{i=1}^{144} a_{5i} x'_{5i}, \quad (5)$$

where

D_{gm} = demand for the gth product in the mth consuming region in which:
g=1 refers to wheat demand; g=2 refers to feed-grain demand and
g=3 refers to oilmeal demand,

a_{ki} = yield per acre of the kth producing activity in the ith
programming region with k=1=wheat, k=2=feed grains, k=3=feed
grains and soybeans, k=4=soybeans and k=5=cotton,

x'_{ki} = level of production (acres) of the kth activity in the ith
programming region,

r = number of programming regions in the mth consuming region,

h_m = amount of wheat transferred into feed grains per unit of the
wheat-to-feed-grain transfer activity in the mth consuming
region,

Y_m = level of the wheat-to-feed-grain transfer activity in the
mth consuming region,

$t_{gmm'}$ = amount of the gth product transported from the mth consuming
region to the m'th consuming region or the amount of the gth
product transported to the mth consuming region from the m'th
consuming region per unit of the lmm'th transportation activity,

$z_{gmm'}$ = level of the activity which transports the gth product from
(to) the mth consuming region to (from) the m'th consuming
region, and

D_c = national demand for cotton lint.

In addition, equation 1 must be minimized subject to the land restraints:

$$L_{Ti} \geq \sum_{k=1}^5 x'_{ki} \quad (6)$$

$$L_{Ci} \geq x'_{5i} \quad (7)$$

$$L_{Si} \geq x'_{4i} \quad (8)$$

where

L_{Ti} = total amount of land available for the k=5 producing activities
in the ith programming region,

L_{Ci} = amount of land available for cotton production in the ith
programming region,

L_{Si} = amount of land available for the soybean activity in the ith
programming region,

and all other symbols are defined as above.

Finally feasible solutions are defined as:

$$x'_{ki} \geq 0; Y_m \geq 0; z_{gmm'} \geq 0. \quad (9)$$